MR Tagging of the Entire Cardiac Cycle: Regional Analysis of Normal Subjects and Hypertrophic Cardiomyopathy Using A New Quantity for Assessment of Regional Cardiac Function

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Introduction:

MR tagging provides for regional quantification of myocardial function. Two key factors currently limit the usefulness of previous techniques: 1) tag fading due to T1 and 2) Loss of 10-30% of the cardiac cycle in gated sequences due to trigger windowing. This abstract presents results from a new sequence that combines a tagging method that allows for tag persistence through the entire cardiac cyle (CSPAMM, Ref. 1) with one that allows acquisition of the entire cardiac cycle in a single breathhold (CAPTOR, Ref. 2). The purpose of this study was to quantify regional cardiac function of all phases of the cardiac cycle including atrial systole. Results are shown for Normal Subjects (NS) and Hypertrophic Cardiomyopathy (HCM).

Methods:

Images were acquired with a 1.5T GE cardiac MRI scanner. Both CSPAMM and CAPTOR were implemented in a Fast Gradient Echo sequence with an Echo-Train readout (FGRE-ET). A 4D B-spline motion analysis method used long axis images to track through plane motion (Ref. 3). Slice following techniques were not used (Ref. 1). Longitudinal displacements were assumed to be small in the motion analysis performed on two HCMs in which no long axis images were acquired. Three NS and four HCM patients were examined. Heart rates (bpm) were 59.1±5.8 in NS and 60.9±7.7 in HCM. Images were segmented using a 3-D template with spatial and temporal interpolation (Ref. 4). Tags were automatically tracked with little intervention using Findtags (Ref. 5).

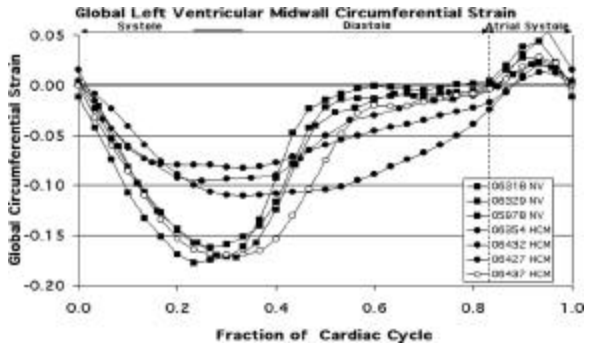

Figure 1

Results:

The regional and global mechanics of both NS and HCM patients were quantified. Figure 1 shows global midwall left ventricular circumferential strain (Ecc), computed from averages of regional assessments, in each of seven patients. The maximum global midwall circumferential shortening strains were -17.1%±0.8% in the NS group and -11.5%±3.8% in the HCM ($p<0.057$). The rate of systolic shortening (%strain/second) in the NS group was 84.7%/s±7.6%/s and 59.2%/s±10.0%/s in the HCM group ($p<0.012$). The rate of diastolic lengthening in the NS group was 99.5%/s±3.0%/s and 32.2%/s±27.8%/s in the HCM group ($p<0.016$). In two of the HCM patients, there is no diastasis phase despite low heart rates. A new measure, presented here, is called the Atrial Systolic Response Ratio (ASRR). ASRR, similar to the E/A ratio (Ref. 5), is the ratio of stretch due to atrial systole in proportion to the stretch due to total diastolic filling. ASRR is an index of ventricular diastolic function. ASRR for global midwall Ecc was 14.1%±3.6% in the NS group. This was found to be regionally homogenous. ASRR in the HCM group was 29.7%±9.2% ($p<0.036$). This quantifies a near two-fold increase of dependence on atrial systole for complete diastolic lengthening. HCM patients exhibited greater regional heterogeneity of ASRR than the NS group. Regional assessment of midwall Ecc ASRR is shown in Figure 2. Some of the regions in the HCM patients show function similar to the average NS data. Other regions are markedly different from the same region in the average NS, suggesting impaired regional diastolic function. HCM exam #06437 might be overlooked upon global function assessment (Fig. 1), but shows marked regional dysfunction compared to the average NS assessment (Fig. 3).

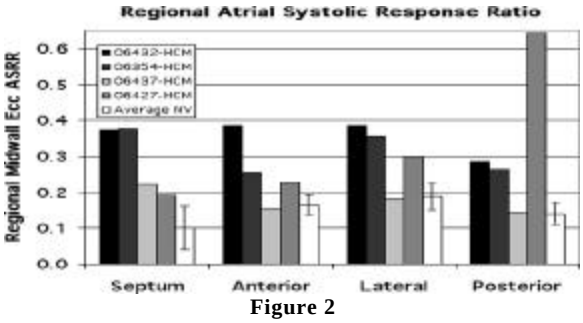

Figure 2

Discussion:

This technique successfully quantified the entire cardiac cycle and assessed a measure similar to E/A ratio. In addition, this technique characterizes clear differences between NS and HCM patients (decreased peak systolic strain, decreased strain rates in systole and diastole, and increased ASRR). Finally, this method allows regional assessment of ASRR, a measure analogous to E/A ratio. ASRR can only be measured if the entire cardiac cycle is imaged. Future work includes true E/A ratio calculations using regional myocardial velocities, assessment of function in an increased number of regional segments, and improvement of SNR with other tagging techniques.

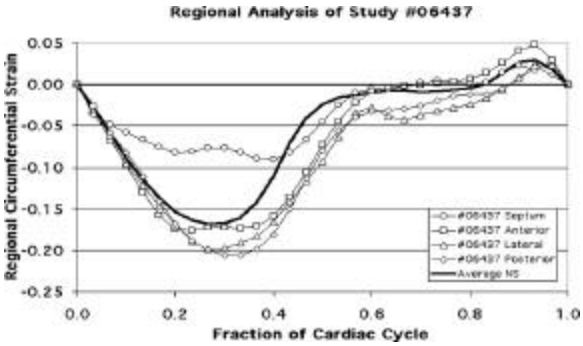

Figure 3

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